

Louis Agassiz, while visiting Scotland in 1840, was one of the first geologists to recognise the evidence of former glaciations in the British landscape. **Colm Jordan** (BGS), **Chris Clark** and **Anna Hughes** (University of Sheffield) explain how the evidence collected over the subsequent decades is being compiled into a coherent resource for climate change researchers.

Glacial ‘climate control’

Ice sheets are highly significant components of the global climate system, affecting atmospheric and oceanic circulation systems, the amount of light reflected off the planet and the hydrological cycle. Reconstructing former ice sheets and their dynamics provides insights into the behaviour of the present-day ice sheets in Greenland and Antarctica and potentially how they will respond to, and affect, future climate change. An understanding of recent glacial episodes in Britain will also help us model how future glacial episodes could affect our landscape.

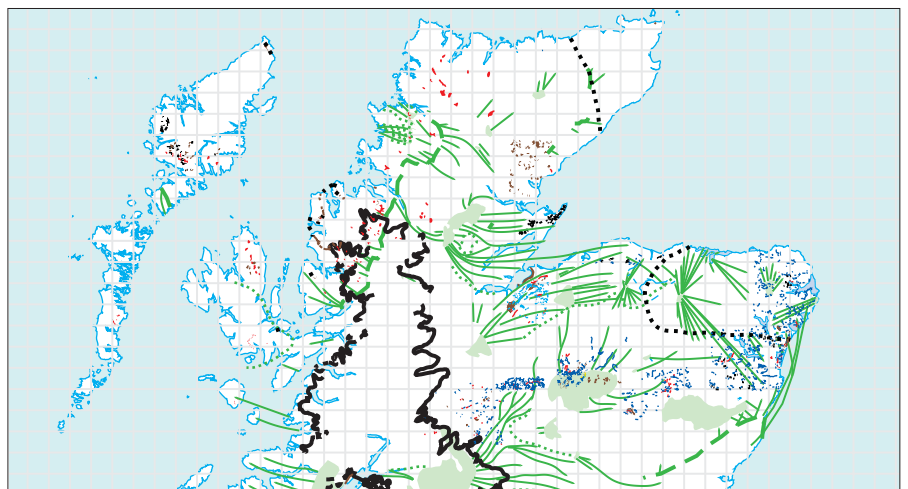
Numerical climate models are increasingly used to reconstruct past, and predict future, climate change. The successful application of these climate models depends on accurate knowledge of the amount of the Earth's surface covered by ice (the cryosphere) and the input of boundary conditions for former ice sheets. Geological evidence of former ice sheets can provide the parameters for climate models as well as testing the accuracy of their outputs. Therefore, ice-sheet reconstructions can form an independent check on climate models as well as refining our understanding of climate and glacial processes.

Reconstructing former ice sheets is a complex process in its own right. Numerical and isostasy-based modelling has been used to investigate the last British ice sheet (BIS). But the influence of topography and presence of multiple independent glaciation centres mean

that the BIS has a complicated geometry and is therefore difficult to model mathematically. Different modelling approaches have provided varying results, especially with respect to the

glacial history of the North Sea, and none of the current models adequately explains the landscape we see today. We are using an approach based on an understanding of the landforms left behind after glaciers have melted to reconstruct where the ice was, as well as its dynamics.

Numerous investigations, primarily by field geologists of the BGS and by university-based academics, have yielded a plethora of publications. They report field evidence relating to the extent and



Glacial landforms map showing over 20 000 glacial landform features compiled from 150 years of published research — part of the North Sheet.

dynamics of the last (Devensian) ice sheet which was at its largest 22 000 years ago but had melted away by about 12 000 years ago. The information base is so large, exceeding 2000 publications, that all the pieces of the jigsaw have never been assembled, until now. BGS Quaternary scientists are working with the University of Sheffield, with funding from the BGS University Collaboration Advisory Committee, to undertake the first systematic approach to compiling 150 years of published research into a coherent synthesis map of Britain that currently contains over 20 000 features.

“ a comprehensive and systematic mapping programme for the whole of the country is a first step towards providing data for a coherent ice-sheet reconstruction ”

A joint BGS and Sheffield University PhD research project is also mapping the glacial landforms for the whole of Britain using digital terrain models (DTMs) — digital representations of topography, and satellite imagery. The landforms are being used to reconstruct the glaciers that covered most of Britain so that we can gauge their impact in relation to climatic and oceanic changes over the last glacial cycle. Our systematic palaeoglaciological approach uses interpretations of remote sensing data with focused fieldwork to complete widespread mapping of glacial geomorphology including:

- bedform lineations recording flow information, e.g. drumlins
- glaciofluvial features, e.g. eskers and meltwater channels
- ice-marginal features, e.g. end moraines.

By analysing the relative ages of cross-cutting glacial features we are able to make a comprehensive reconstruction of both the build up and decay patterns of the ice sheet over time, providing

insights into the role of the BIS in abrupt climate change and the dynamics of ice sheets in marine climates.

Satellite imagery and DTMs are making it possible for us to undertake a comprehensive and systematic mapping programme for the whole of the country. This overcomes the inconsistencies between individual observers and is a first step towards providing data for a coherent ice-sheet reconstruction. The results of such a mapping programme help us to reconstruct ice sheets including:

- retreat patterns
- timing of deglaciation,
- the position of ice divides
- flow configuration
- the location of ice streams
- the vertical extent of the ice
- spatial extent where no record yet exists
- dynamics over time.

The computer-based system is enabling rapid surveying of large areas by a single operator who can apply a well-defined set of criteria for landform identification. Moreover, digital data are easily incorporated into a geographical information system (GIS) where we integrate field studies with satellite information to explore the spatial arrangement of landforms and flow patterns, and export that information for direct use in climate modelling.

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Mosaic of enhanced images from the Landsat satellite.



Digital terrain model (DTM) of Britain based on NEXTMap elevation data from Intermap Technologies.